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(54) **SEARCHING METHOD AND DEVICE FOR MULTILEVEL FLOW TABLE**

(57) Embodiments of the present invention provide a multi-level flow table search method and apparatus, to improve flexibility of configuration of a flow table match field. The method includes: extracting matching information of a data packet when the data packet is received; selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information; searching for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword as a search keyword, and matching the search keyword with the match field; and if matching of a match field of a current-level flow table is completed, executing a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, executing a corresponding action. In the method provided in the embodiments of the present invention, because flow-table match-field configuration information can be configured by using software, a fixed match field becomes a changeable match field. Therefore, flexibility of a flow table match field is improved, and costs incurred by modifying hardware logic when a match field is changed are reduced.

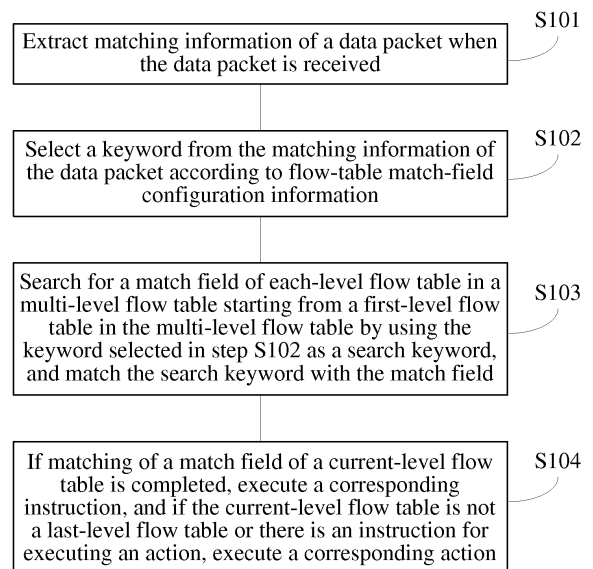


FIG. 1-a

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## Description

[0001] This application claims priority to Chinese Patent Application No. 201310269726.0, filed with the Chinese Patent Office on June 28, 2013 and entitled "MULTI-LEVEL FLOW TABLE SEARCH METHOD AND APPARATUS", which is incorporated herein by reference in its entirety.

## TECHNICAL FIELD

[0002] The present invention relates to the field of communications, and in particular, to a multi-level flow table search method and apparatus.

## BACKGROUND

[0003] With the development of new technologies of network devices, especially for support of programmability and virtualization, the development of network devices trends toward separation of a control plane from a data plane. As one of the technologies, OpenFlow draws widespread attention. An OpenFlow network consists of three parts: an OpenFlow switch, a FlowVisor, and a controller (Controller). The OpenFlow switch is a core component of the entire OpenFlow network, and mainly manages forwarding of a data layer. The FlowVisor performs virtualization on the network. The Controller performs centralized control on the network to implement a function of a control layer. After receiving a data packet, the OpenFlow switch first searches a local flow table (flow table) for a forwarding destination port, and forwards the data packet to the controller if no match is found, and the control layer decides a forwarding port. OpenFlow implements data forwarding on an OpenFlow switch, and implements data forwarding control on a controller, thereby implementing separation of a data forwarding layer from a control layer.

[0004] It can be seen from the foregoing process of processing a data packet in an OpenFlow network that, searching a flow table is an important step. Generally, there are more than one local flow tables, and multiple flow tables are cascaded to form a multi-level flow table. Match fields of an existing multi-level flow table are all fixed multi-level flow-table match fields, where each flow table of the multi-level flow table has a fixed match field. Each flow table has an independent search unit. Once a data packet arrives, a search unit searches a flow table corresponding to the data packet, then obtains an ID of a next flow table by means of search, determines the next flow table to be skipped to, and adds an action corresponding to a search result to an instruction set. Flow table skipping may be skipping over a flow table. According to the stipulation in the OpenFlow protocol, each time after matching is performed on a flow table, an ID of a next flow table may be specified, as long as the ID is greater than an ID of a current table. For example, it is specified that a matching result of a flow table 1 is to skip

to a flow table 3; therefore, the flow table 1 may skip over a flow table 2 and directly skip to the flow table 3.

[0005] A main disadvantage of the foregoing existing multi-level flow table search method lies in lack of flexibility, because each single flow table in a multi-level flow table has a fixed match field, and hardware logic needs to be modified each time a match field is modified.

## SUMMARY

[0006] Embodiments of the present invention provide a multi-level flow table search method and apparatus, to improve flexibility of configuration of a flow table match field.

[0007] According to a first aspect, the present invention provides a multi-level flow table search method, where the method includes:

extracting matching information of a data packet when the data packet is received;  
selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information;  
searching for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword as a search keyword, and matching the search keyword with the match field; and  
if matching of a match field of a current-level flow table is completed, executing a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, executing a corresponding action.

[0008] With reference to the first aspect or the first possible implementation manner of the first aspect, in a second possible implementation manner of the first aspect, after the executing a corresponding instruction and action, the method further includes: modifying the extracted matching information of the data packet.

[0009] With reference to the first aspect, the first possible implementation manner of the first aspect, or the second possible implementation manner of the first aspect, in a third possible implementation manner of the first aspect, the selecting a keyword from the matching information of the data packet includes:

determining matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by a bitmap; and  
forming the keyword by using the determined matching information.

[0010] With reference to the first aspect, the first possible implementation manner of the first aspect, or the second possible implementation manner of the first as-

pect, in a fourth possible implementation manner of the first aspect, the selecting a keyword from the matching information of the data packet includes:

determining matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code; and forming the keyword by using the determined matching information.

**[0011]** According to a second aspect, the present invention provides a multi-level flow table search apparatus, where the apparatus includes:

an extracting module, configured to extract matching information of a data packet when the data packet is received;  
 a keyword generating module, configured to select a keyword from the matching information of the data packet according to flow-table match-field configuration information;  
 a search module, configured to search for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword as a search keyword, and match the search keyword with the match field; and  
 an executing module, configured to: if matching of a match field of a current-level flow table is completed, execute a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, execute a corresponding action.

**[0012]** With reference to the second aspect or the first possible implementation manner of the second aspect, in a second possible implementation manner of the second aspect, the apparatus further includes:

a modifying module, configured to modify the extracted matching information of the data packet.

**[0013]** With reference to the second aspect, the first possible implementation manner of the second aspect, or the second possible implementation manner of the second aspect, in a third possible implementation manner of the second aspect, the keyword generating module includes:

a first determining unit, configured to determine matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by a bit-map; and  
 a first combining unit, configured to form the keyword

by using the determined matching information.

**[0014]** With reference to the second aspect, the first possible implementation manner of the second aspect, or the second possible implementation manner of the second aspect, in a fourth possible implementation manner of the second aspect, the keyword generating module includes:

a second determining unit, configured to determine matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code; and  
 a second combining unit, configured to form the keyword by using the determined matching information.

**[0015]** It can be seen from the foregoing embodiments of the present invention that, because flow-table match-field configuration information is information that can be modified according to a requirement by using software, hardware logic does not need to be modified to change a flow table match field, and a keyword generated according to the flow-table match-field configuration information is matched with a match field in each-level flow table in the multi-level flow table. Compared with the prior art in which each single flow table in a multi-level flow table has a fixed match field and hardware logic needs to be modified each time a match field is changed, in the method provided in the embodiments of the present invention, because flow-table match-field configuration information can be configured by using software, a fixed match field becomes a changeable match field. Therefore, flexibility of a flow table match field is improved, and costs incurred by modifying hardware logic when a match field is changed are reduced.

## BRIEF DESCRIPTION OF DRAWINGS

**[0016]** To describe the technical solutions in the embodiments of the present invention more clearly, the following briefly introduces the accompanying drawings required for describing the prior art or the embodiments. Apparently, the accompanying drawings in the following description show merely some embodiments of the present invention, and a person skilled in the art may still derive other drawings from these accompanying drawings.

FIG. 1-a is a schematic flowchart of a multi-level flow table search method according to an embodiment of the present invention;

FIG. 1-b is a schematic diagram of matching in a multi-level flow table search method according to an embodiment of the present invention;

FIG. 1-c is a schematic diagram of matching in a multi-level flow table search method according to an

other embodiment of the present invention;  
 FIG. 1-d is a schematic diagram of matching in a multi-level flow table search method according to another embodiment of the present invention;  
 FIG. 1-e is a schematic diagram of matching in a multi-level flow table search method according to another embodiment of the present invention;  
 FIG. 2 is a schematic structural diagram of a multi-level flow table search apparatus according to an embodiment of the present invention;  
 FIG. 3 is a schematic structural diagram of a multi-level flow table search apparatus according to another embodiment of the present invention;  
 FIG. 4-a is a schematic structural diagram of a multi-level flow table search apparatus according to another embodiment of the present invention;  
 FIG. 4-b is a schematic structural diagram of a multi-level flow table search apparatus according to another embodiment of the present invention;  
 FIG. 5-a is a schematic structural diagram of a multi-level flow table search apparatus according to another embodiment of the present invention; and  
 FIG. 5-b is a schematic structural diagram of a multi-level flow table search apparatus according to another embodiment of the present invention.

## DESCRIPTION OF EMBODIMENTS

**[0017]** The following clearly and completely describes the technical solutions in the embodiments of the present invention with reference to the accompanying drawings in the embodiments of the present invention. Apparently, the described embodiments are merely some but not all of the embodiments of the present invention. All other embodiments obtained by a person skilled in the art based on the embodiments of the present invention shall fall within the protection scope of the present invention.

**[0018]** FIG. 1-a is a schematic flowchart of a multi-level flow table search method according to an embodiment of the present invention. The method mainly includes S101, S102, S103, and S104, which are described in detail as follows:

S101: Extract matching information of a data packet when the data packet is received.

**[0019]** Matching information of a data packet is information, which is to be matched with content of a match field in a flow table, in the data packet. The so-called flow table (flow table) includes multiple flow entries, and each flow entry is a forwarding rule. For a data packet entering a switch, a forwarding destination port is obtained by querying a flow table. A flow entry includes a header field, a counter, and an operation. The header field, which is an information tuple such as a quintet, is an identifier of the flow entry, and is also a match field of a flow table. Content of the header field is specific information to be matched with extracted matching information of a data packet. The

counter is used to collect statistical data of the flow entry. The operation specifies an operation that should be executed on a data packet matching the flow entry. In the prior art, matching information of a data packet is extracted according to a fixed match field of a single flow table each time; therefore, extraction needs to be performed for multiple times. In contrast, in this embodiment of the present invention, as an exemplary embodiment in which extracting all matching information of a data packet when the data packet is received may be extracting all the matching information of the data packet when the data packet is received, the exemplary embodiment may be extracting all the matching information of the data packet when the data packet is received, where all the matching information may exist in a form of a data structure.

**[0020]** S102: Select a keyword from the matching information of the data packet according to flow-table match-field configuration information.

**[0021]** In the prior art, a match field (match field) of each flow table in a multi-level flow table is fixed; as reflected in hardware, fixed storage spaces are allocated to match fields of these flow tables. If a match field of a flow table needs to be changed, hardware logic needs to be modified, for example, an overall storage space is reallocated, which undoubtedly increases costs. For example, in a multi-level flow table that includes three flow tables, specific content of a match field of a first-level flow table is an IP; specific content of a match field of a second-level flow table is MAC; and specific content of a match field of a third-level flow table is a VLAN ID. If the specific content of the match field of the first-level flow table needs to be changed to a port number, this can be implemented only by modifying specific hardware logic, for example, re-modifying a storage space originally allocated to the match field of the first-level flow table.

**[0022]** In this embodiment of the present invention, a storage space is allocated to a match field in each flow table, and once allocation of the storage space is completed, the match field remains unchanged unless hardware logic is modified; however, a match field, which is to be matched with matching information of a data packet, in a flow table may be identified by using software, and this action is completed by using flow-table match-field configuration information in this embodiment of the present invention. The flow-table match-field configuration information may be configured by using software, and therefore, although the match field of the flow table is fixed, the match field, which is to be matched with the matching information of the data packet, in the flow table can be changed according to a change of the flow-table match-field configuration information. It should be noted that both a flow table in the prior art and a "flow table" involved in identifying a match field, which is to be matched with matching information of a data packet, in the flow table by using software in this embodiment of the present invention are physical flow tables, that is, a physical flow table is corresponding to a fixed physical storage space. In this respect, the flow-table match-field

configuration information mentioned in this embodiment of the present invention is specifically used to identify a match field, which is to be matched with the selected matching information, in a physical flow table by using software.

**[0023]** When extracting all matching information of a data packet when the data packet is received is used as an exemplary embodiment of extracting matching information of the data packet when the data packet is received, and the flow-table match-field configuration information is used to identify a match field, which is to be matched with the selected matching information, in a physical flow table by using software, an embodiment of the selecting the keyword from the matching information of the data packet according to the flow-table match-field configuration information may be: generating the keyword by selecting several pieces of matching information from all the matching information of the data packet according to the flow-table match-field configuration information.

**[0024]** S103: Search for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword selected in step S102 as a search keyword, and match the search keyword with the match field.

**[0025]** S104: If matching of a match field of a current-level flow table is completed, execute a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, execute a corresponding action.

**[0026]** When an embodiment of the foregoing S101 and S102 is: extracting all the matching information of the data packet when the data packet is received and generating the keyword by selecting several pieces of matching information from all the matching information of the data packet according to the flow-table match-field configuration information, as an exemplary embodiment of the present invention, the searching for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword selected in S102 as a search keyword, and matching the search keyword with the match field; and if matching of a match field of a current-level flow table is completed, executing a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, executing a corresponding action may be: searching for a match field of each-level logical flow table in a multi-level logical flow table starting from a first-level logical flow table in the multi-level logical flow table by using the keyword as a search keyword, and matching the search keyword with the match field; and if matching of a match field of a current-level logical flow table is completed, executing a corresponding instruction, and if the current-level logical flow table is not a last-level logical flow table or there is an instruction for executing an action, executing a corresponding action.

**[0027]** It should be noted that the multi-level logical flow

table in this embodiment of the present invention is in contrast with a multi-level flow table including multiple physical flow tables in the prior art. The so-called multi-level logical flow table is formed by cascading logical flow tables, which are obtained by configuring physical flow tables according to the flow-table match-field configuration information involved in the foregoing embodiment. A reason for calling a logical flow table is that a function that a single logical flow table can implement, for example, a match field of the logical flow table is used to match matching information of a data packet, is the same as a function that a single physical flow table can implement; however, no physical storage space is allocated to a single logical flow table; instead, all logical flow tables share one storage space allocated to a physical flow table. Cascading of multiple logical flow tables (that is, a multi-level logical flow table) is also similar to cascading of multiple physical flow tables, for example, in both cases, after a flow table is searched, an ID in the flow table is used to indicate a next flow table to be searched.

**[0028]** In this embodiment of the present invention, executing of an instruction (instruction) includes modifying an action (action) for data, skipping between flow tables, and the like; and executing of an action (action) is an operation performed dedicatedly for a data packet, for example, discarding or forwarding a data packet. If the matching of the match field of the current-level logical flow table is completed and the current-level logical flow table is the last-level logical flow table, a processing procedure for the data packet ends. After the match field of the first-level logical flow table in the multi-level logical flow table is searched for and the search keyword is matched with the match field, methods similar to the methods for searching for the match field of the first-level logical flow table in the multi-level logical flow table and matching the search keyword with the match field may be used to search for a match field of a second-level logical flow table in the multi-level logical flow table and match the search keyword with the match field, and this proceeds until a match field of a last-level logical flow table is searched for and matched. In the prior art, an action (action) of a multi-level flow table pipeline can be executed only after matching of a match field of a last-level flow table is completed, and there are some restrictions on repeated execution of an action by hardware. In contrast, in the method provided in this embodiment of the present invention, because a single logical flow table in a multi-level logical flow table is configurable and a flow table is divided, a multi-level flow table pipeline can be implemented well, and repeated execution of an action can also be implemented.

**[0029]** After the corresponding instruction and action are executed, further, the extracted matching information of the data packet may be modified. If an operation is performed on a header of the data packet in a process of executing matching of a match field of a flow table, for example, the header of the data packet is modified, some of the previously extracted matching information of the

data packet becomes invalid. In this case, all matching information of the data packet does not need to be extracted again, but only some invalid matching information needs to be modified accordingly.

**[0030]** It can be seen from the multi-level flow table search method provided in the foregoing embodiment of the present invention that, a match field, which is to be matched with matching information of a data packet, in a physical flow table may be identified by using flow-table match-field configuration information; because the flow-table match-field configuration information can be modified according to a requirement by using software, the match field in the physical flow table does not need to be modified, and multiple logical flow tables can be obtained to form a multi-level flow table, so that a keyword generated according to the flow-table match-field configuration information is matched with a match field of each-level flow table in the multi-level flow table. Compared with the prior art in which each single flow table in a multi-level flow table has a fixed match field and hardware logic needs to be modified each time a match field is changed, in the method provided in this embodiment of the present invention, because flow-table match-field configuration information can be configured by using software, a generated keyword is also changeable. This is equivalent to that a physical flow table becomes a logical flow table, and a fixed match field becomes a changeable match field. Therefore, flexibility of a flow table match field is improved, and costs incurred by modifying hardware logic when a match field is changed are reduced.

**[0031]** For the foregoing embodiment, an embodiment of the selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information in the present invention may be: determining matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by a bitmap, and forming the keyword by using the determined matching information; and preferably may be: determining several pieces of matching information, which are used for flow table match field matching, in all the matching information of the data packet according to the flow-table match-field configuration information represented by a bitmap, and forming the keyword by using the determined several pieces of matching information, so as to use the keyword as a search keyword to match a match field, which is configured according to the flow-table match-field configuration information, in the physical flow table.

**[0032]** In order to describe the foregoing embodiment of the determining several pieces of matching information, which are used for flow table match field matching, in all the matching information of the data packet according to the flow-table match-field configuration information represented by a bitmap, and forming the keyword by using the determined several pieces of matching information, an example is used in the following for further description.

**[0033]** It is assumed that when the data packet is received, all the matching information, such as a MAC address, a VLAN ID, an IP address, and a port number, of the data packet is extracted. When the flow-table match-field configuration information is represented by a bitmap (bitmap), "1" is used to indicate that a keyword generated by selecting several pieces of matching information from all the matching information according to the flow-table match-field configuration information is valid, and "0" is used to indicate that a keyword generated by selecting several pieces of matching information from all the matching information according to the flow-table match-field configuration information is invalid. Because a match field, which is to be matched with the selected matching information, in a physical flow table is also indicated in the flow-table match-field configuration information, in the flow-table match-field configuration information represented by a bitmap, "1" also indicates a match field, which is to be matched with the selected matching information, in a physical flow table, and "0" indicates a match field, which is not to be matched with the selected matching information, in a physical flow table, that is, the match field in the physical flow table is masked. As shown in FIG. 1-b, that all the matching information of the data packet is a MAC address, a VLAN ID, an IP address, and a port number is used as an example. It is assumed that the flow-table match-field configuration information represented by a bitmap is "1001", and match fields in a physical flow table include a match field 1, a match field 2, a match field 3, and a match field 4, which correspondingly include content: a MAC address, a VLAN ID, an IP address, and a port number respectively. According to the foregoing meanings of "1" and "0" in the flow-table match-field configuration information represented by a bitmap, it indicates that among the four pieces of matching information: the MAC address, the VLAN ID, the IP address, and the port number, the MAC address and the port number are selected as a search keyword to be matched with the match field 1 and the match field 4 in the physical flow table, while the match field 3 and the match field 4 in the physical flow table are masked and are not involved in matching of the matching information of the data packet. If a match field, which is to be matched with the matching information, in a physical flow table needs to be modified, in this embodiment of the present invention, hardware logic does not need to be modified to obtain a new physical flow table, but only the flow-table match-field configuration information needs to be modified. For example, if match fields, which are to be matched with the matching information, in the physical flow table need to be changed from the match field 1 and the match field 4, which are originally used for matching, to the match field 2 and the match field 4, only the foregoing flow-table match-field configuration information represented by a bitmap needs to be changed to "0101". In this way, according to the modified flow-table match-field configuration information, among the four pieces of matching information: the

MAC address, the VLAN ID, the IP address, and the port number, the VLAN ID and the port number are selected as a search keyword to be matched with the match field 2 and the match field 4 in the physical flow table, as shown in FIG. 1-c.

**[0034]** For the foregoing embodiment, another embodiment of the selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information in the present invention may be: determining matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code, and forming the keyword by using the determined matching information; and preferably may be: determining several pieces of matching information, which are used for flow table match field matching, in all the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code, and forming the keyword by using the determined several pieces of matching information, so as to use the keyword as a search keyword to match a match field, which is configured according to the flow-table match-field configuration information, in the physical flow table.

**[0035]** In order to describe the foregoing embodiment of the determining several pieces of matching information, which are used for flow table match field matching, in all the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code, and forming the keyword by using the determined several pieces of matching information, an example is used in the following for further description.

**[0036]** It is assumed that when the data packet is received, all the matching information, such as a MAC address, a VLAN ID, an IP address, and a port number, of the data packet is extracted. When the flow-table match-field configuration information is represented by fixed code, it indicates that a keyword generated by selecting several pieces of matching information from all the matching information according to the flow-table match-field configuration information is corresponding to the fixed code. Because a match field, which is to be matched with the selected matching information, in a physical flow table is also indicated in the flow-table match-field configuration information, a match field, which is to be matched with the selected matching information, in a physical flow table is also indicated in the flow-table match-field configuration information represented by fixed code. As shown in FIG. 1-d, that all the matching information of the data packet is a MAC address, a VLAN ID, an IP address, and a port number is used as an example. It is assumed that the flow-table match-field configuration information represented by fixed code is "0x15", which is corresponding to keywords "MAC address" and "port number" that are generated by selecting several pieces of matching information from all the matching

information. Match fields in a physical flow table include a match field 1, a match field 2, a match field 3, and a match field 4, which correspondingly include content: a MAC address, a VLAN ID, an IP address, and a port number respectively. According to the foregoing meaning of the flow-table match-field configuration information represented by fixed code, it indicates that among the four pieces of matching information: the MAC address, the VLAN ID, the IP address, and the port number, "the MAC address" and "the port number" are selected as a search keyword to be matched with the match field 1 and the match field 4 in the physical flow table. If a match field, which is to be matched with the matching information, in a physical flow table needs to be modified, in this embodiment of the present invention, hardware logic does not need to be modified to obtain a new physical flow table, but only the flow-table match-field configuration information needs to be modified. For example, if match fields, which are to be matched with the matching information, in the physical flow table need to be changed from the match field 1 and the match field 4, which are originally used for matching, to the match field 2 and the match field 4, only the foregoing flow-table match-field configuration information represented by fixed code "0x15" needs to be modified, for example, modified to "0x24". In this way, according to the modified flow-table match-field configuration information, among the four pieces of matching information: the MAC address, the VLAN ID, the IP address, and the port number, the VLAN ID and the port number are selected as a search keyword to be matched with the match field 2 and the match field 4 in the physical flow table, as shown in FIG. 1-e.

**[0037]** Without loss of generality, for the foregoing extracted matching information, such as the MAC address, the VLAN ID, the IP address, and the port number, of the data packet, if the flow-table match-field configuration information represented by a bitmap (bitmap) is, for example, "1010" ("1" indicates that the bit is valid, and "0" indicates that the bit is invalid), the search keyword is a combination of the MAC address and the IP address, and is used for matching match fields, which include the content: the MAC address and the IP address respectively, in the physical flow table. For the foregoing extracted matching information, such as the MAC address, the VLAN ID, the IP address, and an ACL rule, of the data packet, if the flow-table match-field configuration information represented by fixed code is, for example, "0x13", the search keyword is a combination of the MAC address and the IP address, and a formed search keyword may be a combination of the MAC address, the IP address, and the like.

**[0038]** FIG. 2 is a schematic structural diagram of a multi-level flow table search apparatus according to an embodiment of the present invention. For ease of description, only a part related to this embodiment of the present invention is shown. The multi-level flow table search apparatus shown in FIG. 2 includes an extracting module 201, a keyword generating module 202, a search

module 203, and an executing module 204.

**[0039]** The extracting module 201 is configured to extract matching information of a data packet when the data packet is received.

**[0040]** Matching information of a data packet is information, which is to be matched with content of a match field in a flow table, in the data packet. The so-called flow table (flow table) includes multiple flow entries, and each flow entry is a forwarding rule. For a data packet entering a switch, a forwarding destination port is obtained by querying a flow table. A flow entry includes a header field, a counter, and an operation. The header field, which is an information tuple such as a quintet, is an identifier of the flow entry, and is also a match field of a flow table. Content of the header field is specific information to be matched with extracted matching information of a data packet. The counter is used to collect statistical data of the flow entry. The operation specifies an operation that should be executed on a data packet matching the flow entry. In the prior art, matching information of a data packet is extracted according to a fixed match field of a single flow table each time; therefore, extraction needs to be performed for multiple times. In contrast, in this embodiment of the present invention, as an exemplary embodiment, the extracting module 201 may extract all the matching information of the data packet when the data packet is received, where all the matching information may exist in a form of a data structure.

**[0041]** The keyword generating module 202 is configured to select a keyword from the matching information of the data packet according to flow-table match-field configuration information.

**[0042]** In the prior art, a match field (match field) of each flow table in a multi-level flow table is fixed; as reflected in hardware, fixed storage spaces are allocated to match fields of these flow tables. If a match field of a flow table needs to be changed, hardware logic needs to be modified, for example, an overall storage space is reallocated, which undoubtedly increases costs. For example, in a multi-level flow table that includes three flow tables, specific content of a match field of a first-level flow table is an IP; specific content of a match field of a second-level flow table is MAC; and specific content of a match field of a third-level flow table is a VLAN ID. If the specific content of the match field of the first-level flow table needs to be changed to a port number, this can be implemented only by modifying specific hardware logic, for example, re-modifying a storage space originally allocated to the match field of the first-level flow table.

**[0043]** In this embodiment of the present invention, a storage space is allocated to a match field in each flow table, and once allocation of the storage space is completed, the match field remains unchanged unless hardware logic is modified; however, a match field, which is to be matched with matching information of a data packet, in a flow table may be identified by using software, and this action is completed by using flow-table match-field configuration information in this embodiment of the

present invention. The flow-table match-field configuration information may be configured by using software, and therefore, although the match field of the flow table is fixed, the match field, which is to be matched with the matching information of the data packet, in the flow table can be changed according to a change of the flow-table match-field configuration information. It should be noted that both a flow table in the prior art and a "flow table" involved in identifying a match field, which is to be matched with matching information of a data packet, in the flow table by using software in this embodiment of the present invention are physical flow tables, that is, a physical flow table is corresponding to a fixed physical storage space. In this respect, the flow-table match-field configuration information mentioned in this embodiment of the present invention is specifically used to identify a match field, which is to be matched with the selected matching information, in a physical flow table by using software.

**[0044]** When the extracting module 201 extracts the matching information of the data packet when the data packet is received, and the flow-table match-field configuration information is used to identify a match field, which is to be matched with the selected matching information, in a physical flow table by using software, an embodiment in which the keyword generating module 202 selects the keyword from the matching information of the data packet according to the flow-table match-field configuration information may be: generating the keyword by selecting several pieces of matching information from all the matching information of the data packet according to the flow-table match-field configuration information.

**[0045]** The search module 203 is configured to search for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword as a search keyword, and match the search keyword with the match field.

**[0046]** The executing module 204 is configured to: if matching of a match field of a current-level flow table is completed, execute a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, execute a corresponding action.

**[0047]** When the extracting module 201 extracts the matching information of the data packet when the data packet is received, the flow-table match-field configuration information is used to identify the match field, which is to be matched with the selected matching information, in the physical flow table by using the software, and the keyword generating module 202 generates the keyword by selecting the several pieces of matching information from all the matching information of the data packet according to the flow-table match-field configuration information, the search module 203 is specifically configured to search for a match field of each-level logical flow table in a multi-level logical flow table starting from a first-level logical flow table in the multi-level logical flow table by using the keyword generated by the keyword generating

module 202 as a search keyword, and match the search keyword with the match field; and the executing module 204 is specifically configured to: if matching of a match field of a current-level logical flow table is completed, execute a corresponding instruction, and if the current-level logical flow table is not a last-level logical flow table or there is an instruction for executing an action, execute a corresponding action.

**[0048]** It should be noted that in the multi-level flow table search apparatus shown in FIG. 2, the multi-level logical flow table is in contrast with a multi-level flow table including multiple physical flow tables in the prior art. The so-called multi-level logical flow table is formed by cascading logical flow tables, which are obtained by configuring physical flow tables according to the flow-table match-field configuration information involved in the foregoing embodiment. A reason for calling a logical flow table is that a function that a single logical flow table can implement, for example, a match field of the logical flow table is used to match matching information of a data packet, is the same as a function that a single physical flow table can implement; however, no physical storage space is allocated to a single logical flow table; instead, all logical flow tables share one storage space allocated to a physical flow table. Cascading of multiple logical flow tables (that is, a multi-level logical flow table) is also similar to cascading of multiple physical flow tables, for example, in both cases, after a flow table is searched, an ID in the flow table is used to indicate a next flow table to be searched. Executing of an instruction (instruction) includes modifying an action (action) for data, skipping between flow tables, and the like; and executing of an action (action) is an operation performed dedicatedly for a data packet, for example, discarding or forwarding a data packet. If the matching of the match field of the current-level logical flow table is completed and the current-level logical flow table is the last-level logical flow table, a processing procedure for the data packet ends. After the match field of the first-level logical flow table in the multi-level logical flow table is searched for and the search keyword is matched with the match field, methods similar to the methods for searching for the match field of the first-level logical flow table in the multi-level logical flow table and matching the search keyword with the match field may be used to search for a match field of a second-level logical flow table in the multi-level logical flow table and match the search keyword with the match field, and this proceeds until a match field of a last-level logical flow table is searched for and matched. In the prior art, an action (action) of a multi-level flow table pipeline can be executed only after matching of a match field of a last-level flow table is completed, and there are some restrictions on repeated execution of an action by hardware. In contrast, in the method provided in this embodiment of the present invention, because a single logical flow table in a multi-level logical flow table is configurable and a flow table is divided, a multi-level flow table pipeline can be implemented well, and repeated execution of an

action can also be implemented.

**[0049]** It should be noted that in the implementation manner of the multi-level flow table search apparatus shown in FIG. 2, division of the functional modules is merely exemplary. In an actual application, according to a requirement such as a corresponding hardware configuration requirement or consideration of convenient implementation of software, the foregoing functions may be allocated to different functional modules for implementation, that is, an inner structure of the multi-level flow table search apparatus is divided into different functional modules, so as to implement some or all of the foregoing described functions. In addition, in an actual application, a corresponding functional module in this embodiment may be implemented by corresponding hardware, or may be implemented by corresponding hardware executing corresponding software. For example, the foregoing extracting module may be hardware having the foregoing function of executing the extracting of matching information of a data packet when the data packet is received, for example, an extractor, or may be a general processor or another hardware device capable of executing a corresponding computer program to implement the foregoing function. For another example, the foregoing keyword generating module may be hardware having the foregoing function of selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information, for example, a keyword generator, or may be a general processor or another hardware device capable of executing a corresponding computer program to implement the foregoing function (the foregoing description rule applies to all the embodiments provided in this specification).

**[0050]** It can be seen from the foregoing multi-level flow table search apparatus shown in FIG. 2, because flow-table match-field configuration information is information that can be modified according to a requirement by using software, hardware logic does not need to be modified to change a flow table match field, and a keyword generated according to the flow-table match-field configuration information is matched with a match field in each-level flow table in the multi-level flow table. Compared with the prior art in which each single flow table in a multi-level flow table has a fixed match field and hardware logic needs to be modified each time a match field is changed, in the method provided in this embodiment of the present invention, because flow-table match-field configuration information can be configured by using software, a fixed match field becomes a changeable match field. Therefore, flexibility of a flow table match field is improved, and costs incurred by modifying hardware logic when a match field is changed are reduced.

**[0051]** In a multi-level flow table pipeline in the prior art, each flow table has an independent search unit. Because logical functions of search units are similar to some degree, some logical resources are wasted. In the multi-level flow table search apparatus shown in FIG. 2, a multi-level flow table is searched cyclically; although a match

field of each flow table is configured by using software, searches are performed in a same module, which can implement sharing of one search module 203 among tables with different match fields and save some logical resources.

**[0052]** The multi-level flow table search apparatus shown in FIG. 2 may further include a modifying module 301, as shown in FIG. 3 showing a multi-level flow table search apparatus according to another embodiment of the present invention. The modifying module 301 modifies the matching information, which is extracted by the extracting module 201, of the data packet.

**[0053]** In the multi-level flow table search apparatus shown in any one of FIG. 2 and FIG. 3, the keyword generating module 202 includes a first determining unit 401 and a first combining unit 402, which are as shown in a multi-level flow table search apparatus shown in any one of FIG. 4-a and FIG. 4-b.

**[0054]** The first determining unit 401 is configured to determine matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by a bitmap; and the first combining unit 402 is configured to form the keyword by using the determined matching information.

**[0055]** In the multi-level flow table search apparatus shown in any one of FIG. 4-a and FIG. 4-b, for the execution of the first determining unit 401 and the first combining unit 402, reference may be made to the foregoing method embodiments corresponding to FIG. 1-b and FIG. 1-c, and beneficial effects of the first determining unit 401 and the first combining unit 402 are the same as those of the method embodiments corresponding to FIG. 1-b and FIG. 1-c, and are not described again herein.

**[0056]** In the multi-level flow table search apparatus shown in any one of FIG. 2 and FIG. 3, the keyword generating module 202 includes a second determining unit 501 and a second combining unit 502, which are as shown in a multi-level flow table search apparatus shown in any one of FIG. 5-a and FIG. 5-b.

**[0057]** The second determining unit 501 is configured to determine matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code; and the second combining unit 502 is configured to form the keyword by using the determined matching information.

**[0058]** In the multi-level flow table search apparatus shown in any one of FIG. 5-a and FIG. 5-b, for the execution of the second determining unit 501 and the second combining unit 502, reference may be made to the foregoing method embodiments corresponding to FIG. 1-d and FIG. 1-e, and beneficial effects of the second determining unit 501 and the second combining unit 502 are the same as those of the method embodiments corresponding to FIG. 1-d and FIG. 1-e, and are not described again herein.

**[0059]** An embodiment of the present invention further

provides a multi-level flow table search device. The device includes a memory and one or more programs, where the one or more programs are stored in the memory, and are configured to be executed by one or more processors, and the one or more programs include instructions for performing the following operations:

extracting matching information of a data packet when the data packet is received;  
selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information;  
searching for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword as a search keyword, and matching the search keyword with the match field; and  
if matching of a match field of a current-level flow table is completed, executing a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, executing a corresponding action.

**[0060]** Assuming that the foregoing is a first possible implementation manner, in a third possible implementation manner provided based on the first possible implementation manner, the memory of the device further includes an instruction for performing the following operation:

modifying the extracted matching information of the data packet.

**[0061]** In a third possible implementation manner provided based on the first or second possible implementation manner, the memory of the device further includes instructions for performing the following operations:

determining matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by a bitmap; and  
forming the keyword by using the determined matching information.

**[0062]** In a fourth possible implementation manner provided based on the first or second possible implementation manner, the memory of the device further includes instructions for performing the following operations:

determining matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code; and  
forming the keyword by using the determined matching information.

**[0063]** As another aspect, another embodiment of the present invention further provides a computer readable storage medium, where the computer readable storage medium may be a computer readable storage medium included in the memory in the foregoing embodiment, or may be a computer readable storage medium that exists independently and is not installed into a terminal. The computer readable storage medium stores one or more programs, where the one or more programs are executed by one or more processors to execute a multi-level flow table search method. The method includes:

extracting matching information of a data packet when the data packet is received;  
 selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information;  
 searching for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword as a search keyword, and matching the search keyword with the match field; and  
 if matching of a match field of a current-level flow table is completed, executing a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, executing a corresponding action.

**[0064]** Assuming that the foregoing is a first possible implementation manner, in a second possible implementation manner provided based on the first possible implementation manner, after the executing a corresponding instruction and action, the method further includes:

modifying the extracted matching information of the data packet.

**[0065]** In a third possible implementation manner provided based on the first or second possible implementation manner, the selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information includes:

determining matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by a bitmap; and  
 forming the keyword by using the determined matching information.

**[0066]** In a fourth possible implementation manner provided based on the first or second possible implementation manner, the selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information includes:

determining matching information, which is used for

flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code; and  
 forming the keyword by using the determined matching information.

**[0067]** It should be noted that content such as information exchange between the modules/units of the apparatus and the execution processes thereof is based on the same idea as the method embodiments of the present invention, and produces the same technical effects as the method embodiments of the present invention. For specific content, reference may be made to the description in the method embodiments of the present invention, and details are not described herein again.

**[0068]** A person of ordinary skill in the art may understand that all or some of the methods in the foregoing embodiments may be implemented by a program instructing relevant hardware. The program may be stored in a computer-readable storage medium. The storage medium may include: a read-only memory (ROM, Read Only Memory), a random access memory (RAM, Random Access Memory), a magnetic disk, or an optical disc.

**[0069]** A person of ordinary skill in the art may be aware that, in combination with the examples described in the embodiments disclosed in this specification, units and algorithm steps can be implemented by electronic hardware or a combination of computer software and electronic hardware. Whether the functions are performed by hardware or software depends on particular applications and design constraint conditions of the technical solutions. A person skilled in the art may use different methods to implement the described functions for each particular application, but it should not be considered that such implementation goes beyond the scope of the present invention.

**[0070]** The multi-level flow table search method and apparatus provided in the embodiments of the present invention are described above in detail. Specific examples are used in this specification to describe the principle and implementation manners of the present invention, but the foregoing descriptions of the embodiments are merely intended to facilitate understanding of the method and core idea of the present invention. Meanwhile, a person of ordinary skill in the art may make modifications to the specific implementation manners and application scope according to the idea of the present invention. In conclusion, the content of this specification shall not be understood as a limitation on the present invention.

## Claims

1. A multi-level flow table search method, wherein the method comprises:

extracting matching information of a data packet

when the data packet is received;  
 selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information;  
 searching for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword as a search keyword, and matching the search keyword with the match field; and  
 if matching of a match field of a current-level flow table is completed, executing a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, executing a corresponding action.

2. The method according to claim 1, wherein after the executing a corresponding instruction and action, the method further comprises:

modifying the extracted matching information of the data packet.

3. The method according to any one of claims 1 to 2, wherein the selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information comprises:

determining matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by a bitmap; and forming the keyword by using the determined matching information.

4. The method according to any one of claims 1 to 2, wherein the selecting a keyword from the matching information of the data packet according to flow-table match-field configuration information comprises:

determining matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code; and forming the keyword by using the determined matching information.

5. A multi-level flow table search apparatus, wherein the apparatus comprises:

an extracting module, configured to extract matching information of a data packet when the data packet is received;  
 a keyword generating module, configured to select a keyword from the matching information of

the data packet according to flow-table match-field configuration information;  
 a search module, configured to search for a match field of each-level flow table in a multi-level flow table starting from a first-level flow table in the multi-level flow table by using the keyword as a search keyword, and match the search keyword with the match field; and  
 an executing module, configured to: if matching of a match field of a current-level flow table is completed, execute a corresponding instruction, and if the current-level flow table is not a last-level flow table or there is an instruction for executing an action, execute a corresponding action.

6. The apparatus according to claim 5, wherein the apparatus further comprises:

a modifying module, configured to modify the extracted matching information of the data packet.

7. The apparatus according to any one of claims 5 to 6, wherein the keyword generating module comprises:

a first determining unit, configured to determine matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by a bitmap; and  
 a first combining unit, configured to form the keyword by using the determined matching information.

8. The apparatus according to any one of claims 5 to 6, wherein the keyword generating module comprises:

a second determining unit, configured to determine matching information, which is used for flow table match field matching, in the matching information of the data packet according to the flow-table match-field configuration information represented by fixed code; and  
 a second combining unit, configured to form the keyword by using the determined matching information.

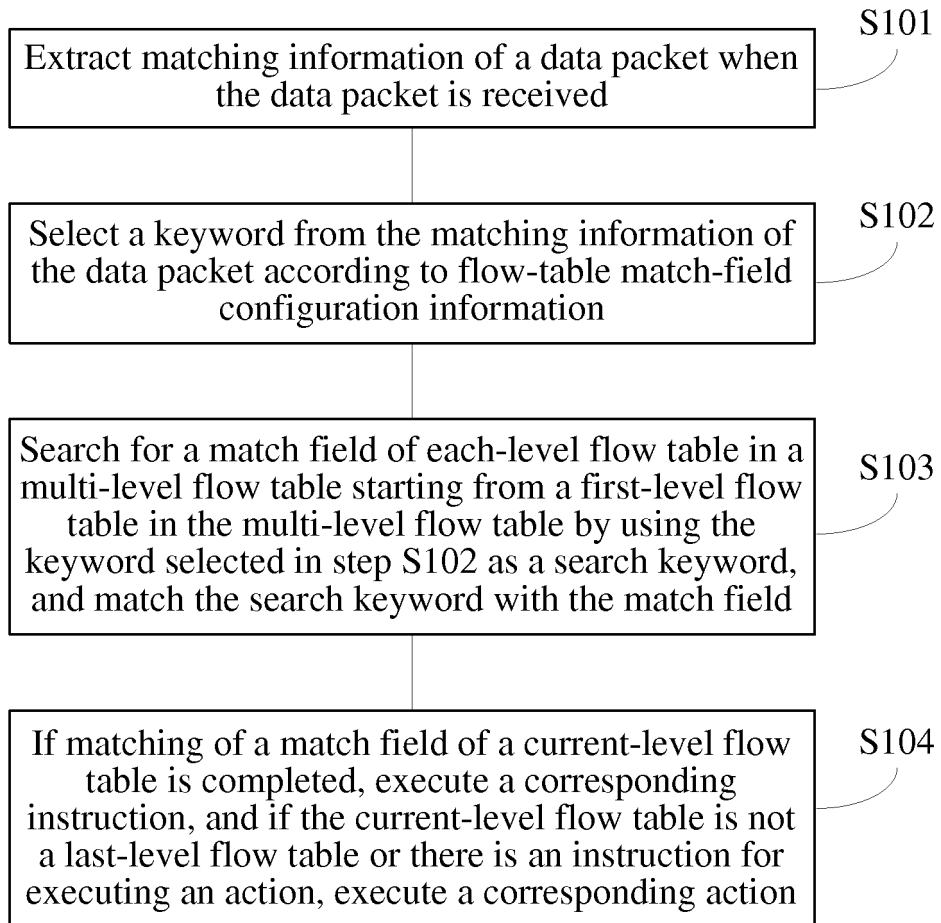


FIG. 1-a

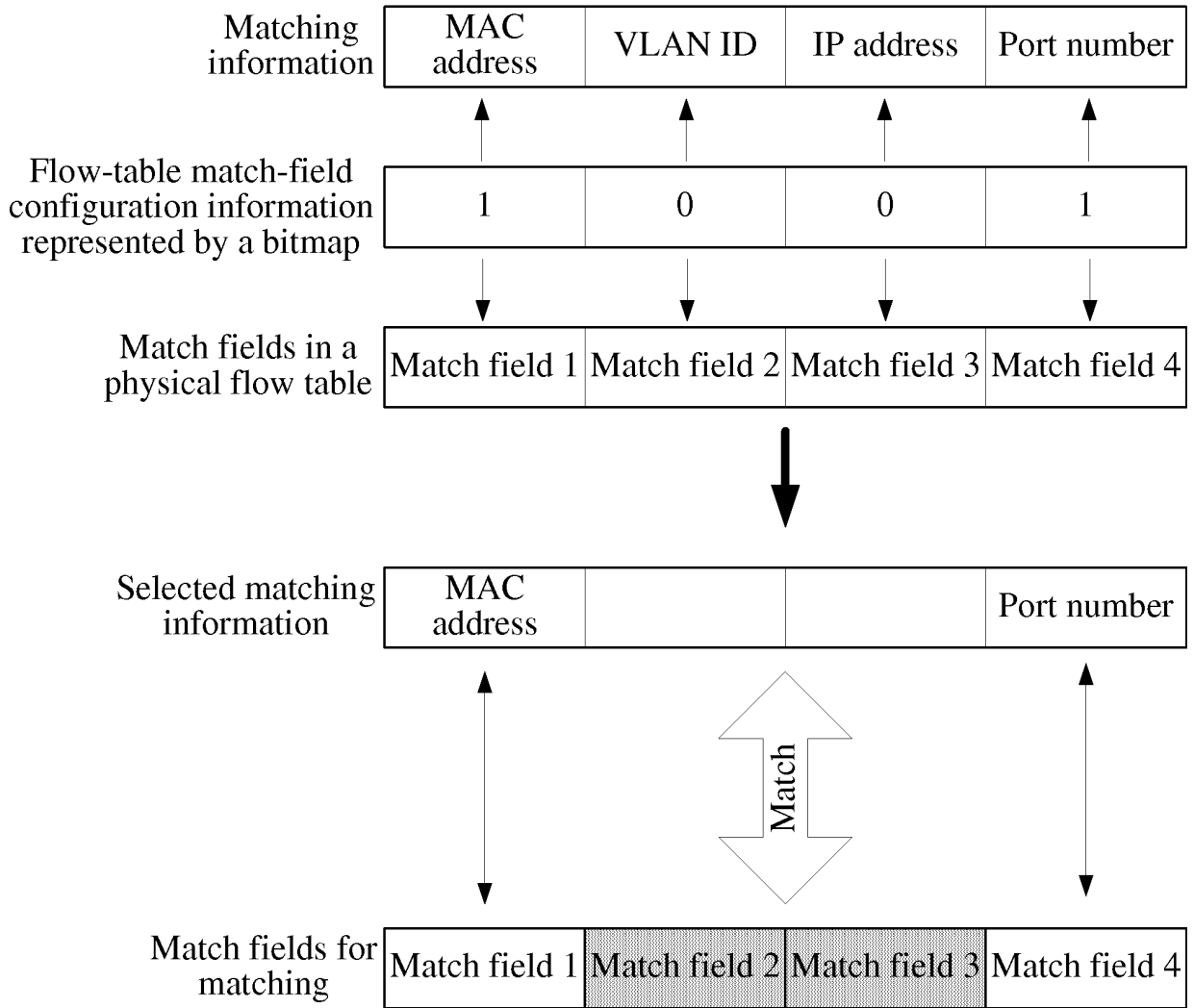


FIG. 1-b

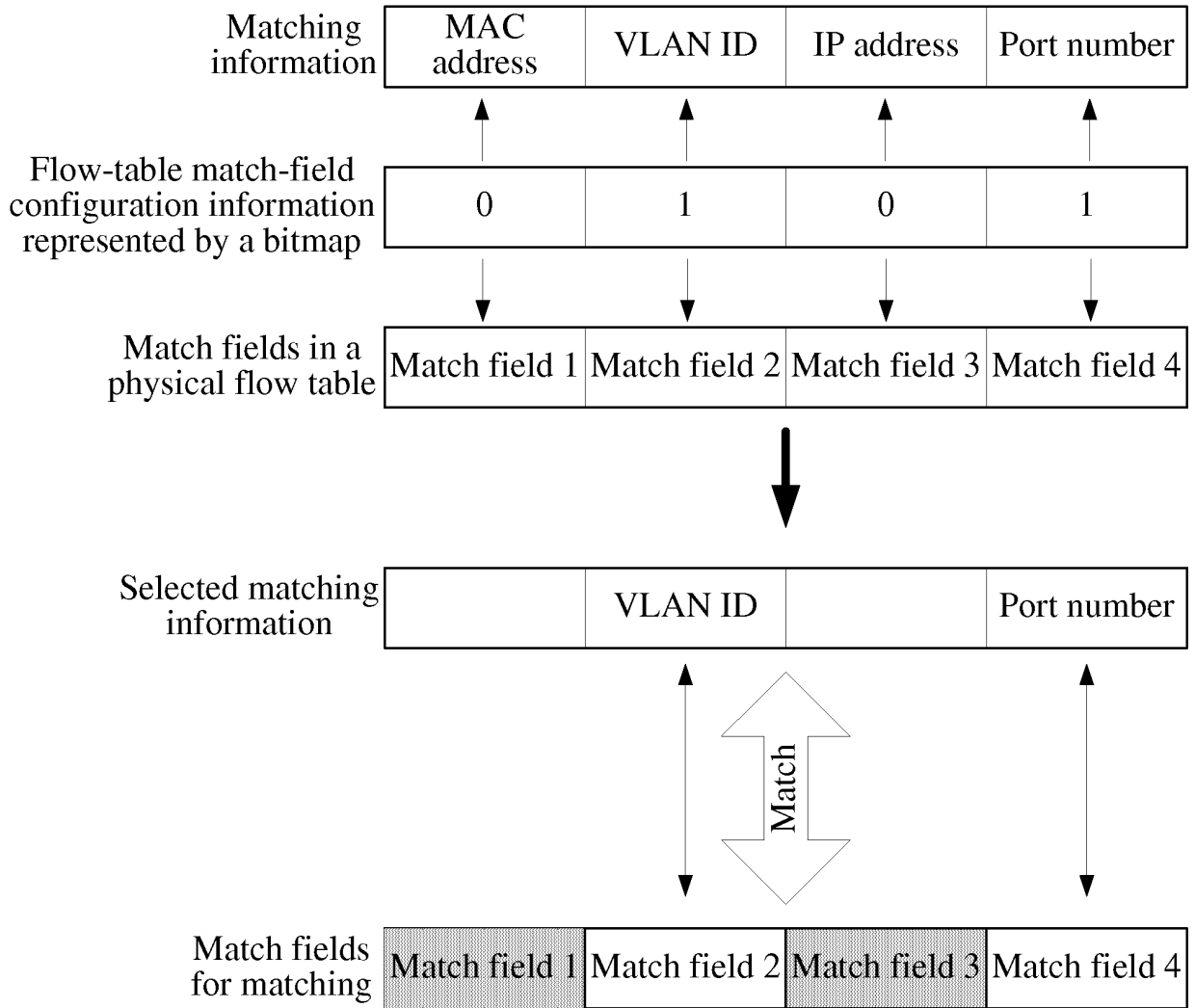


FIG. 1-c

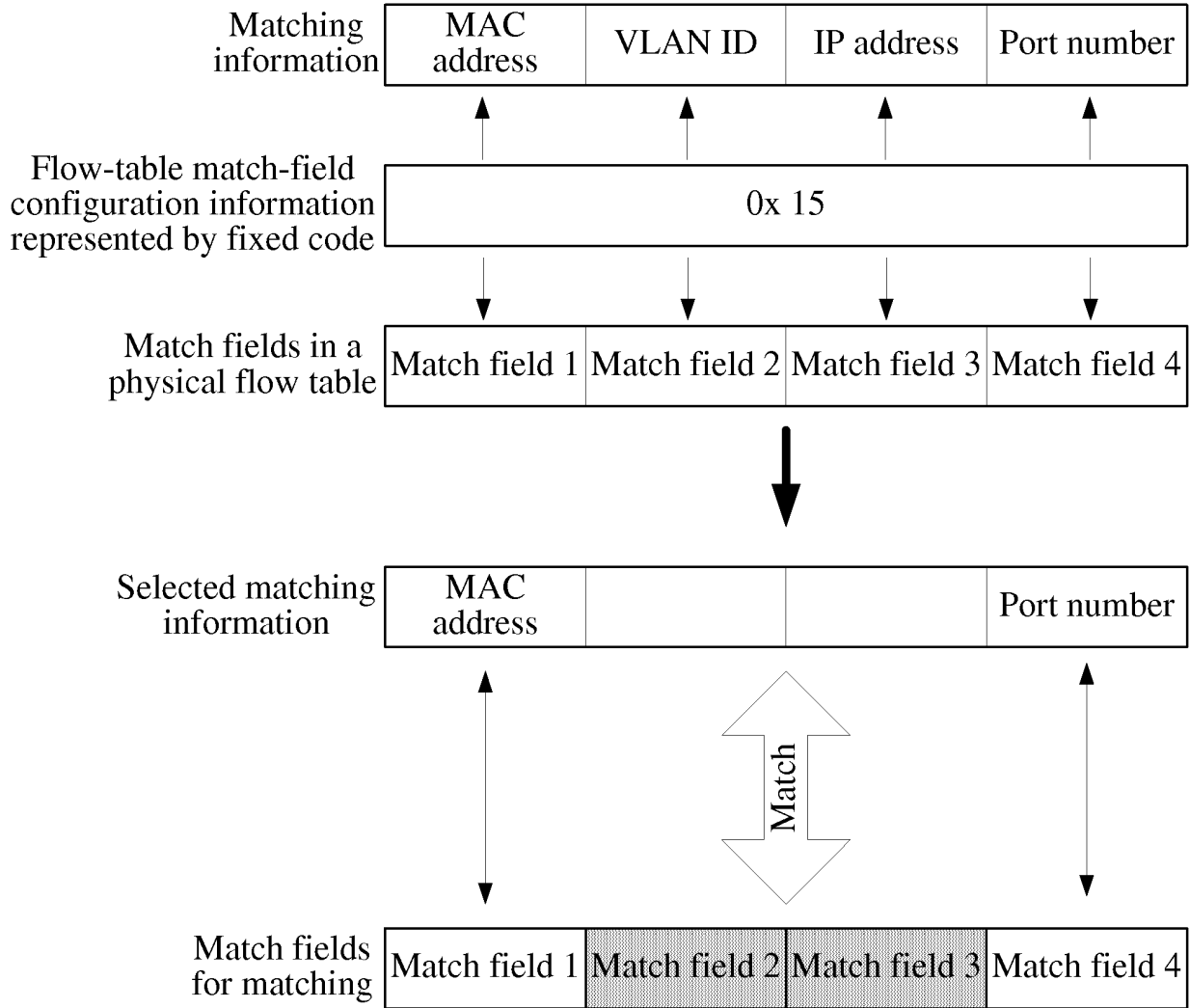


FIG. 1-d

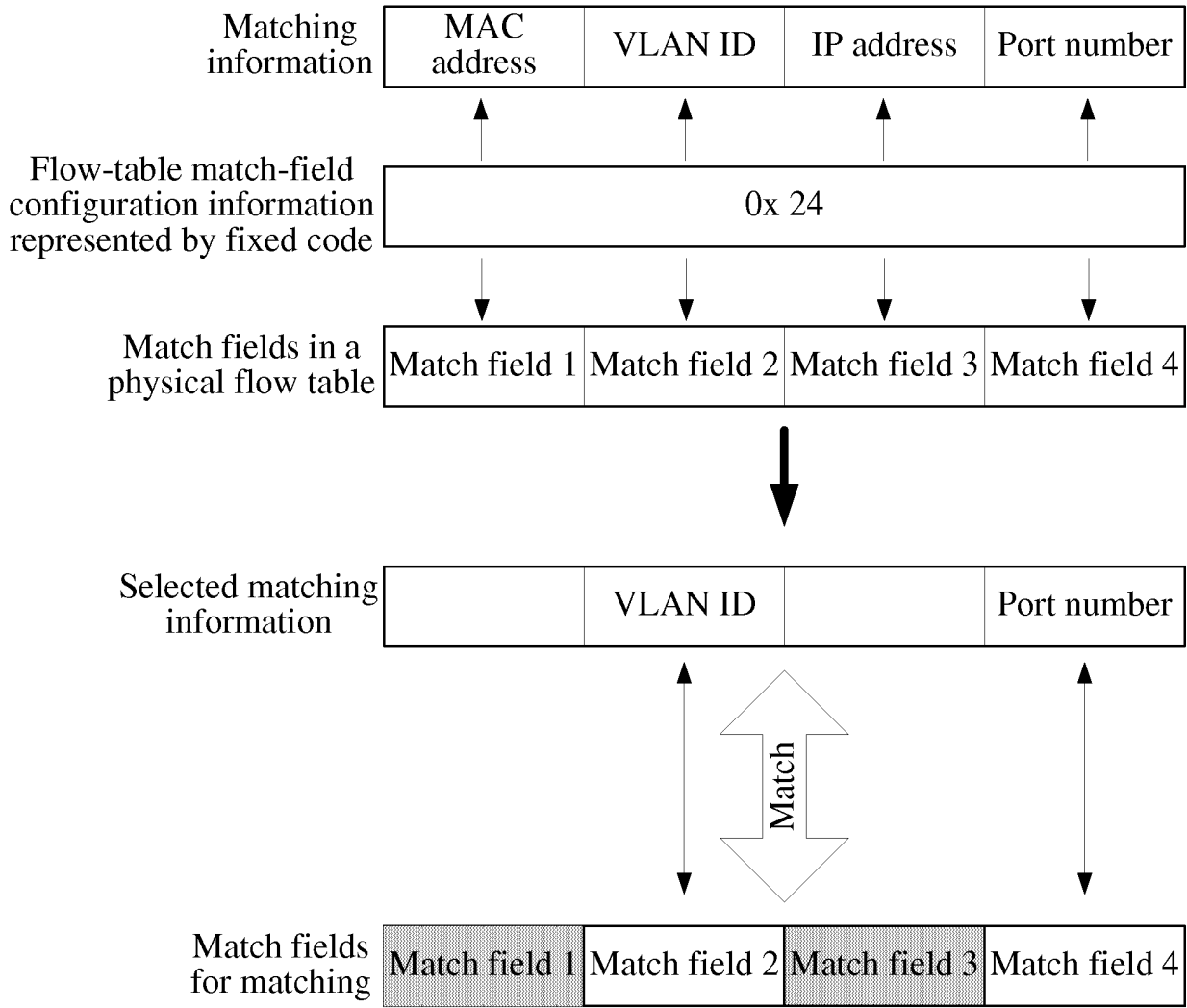


FIG. 1-e

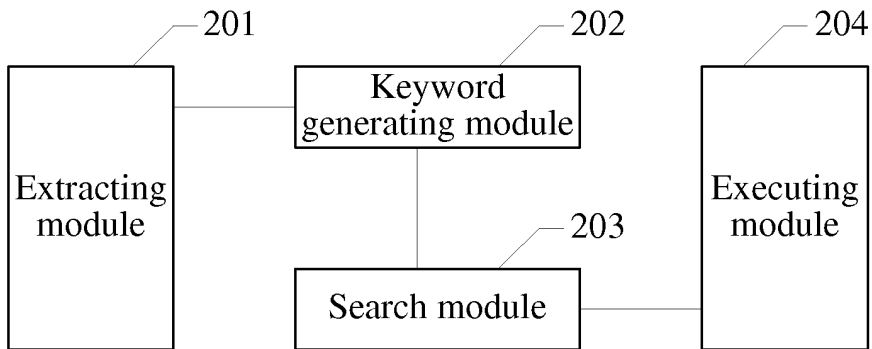


FIG. 2

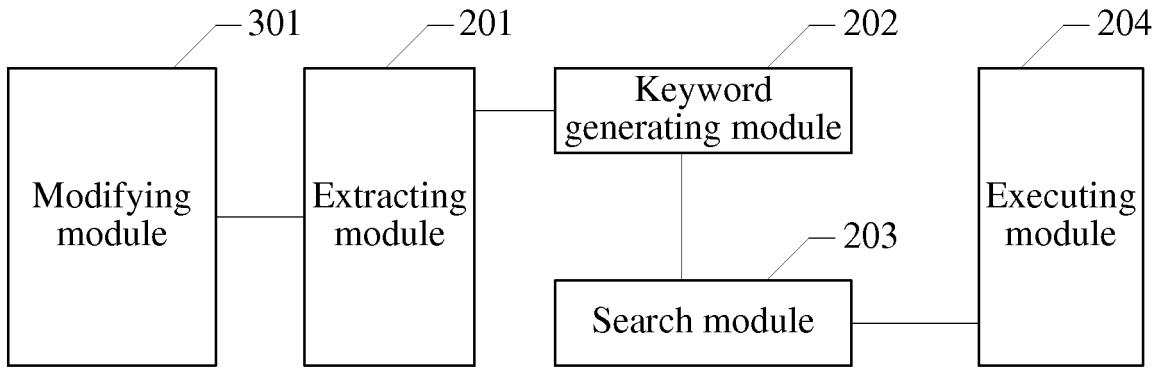


FIG. 3

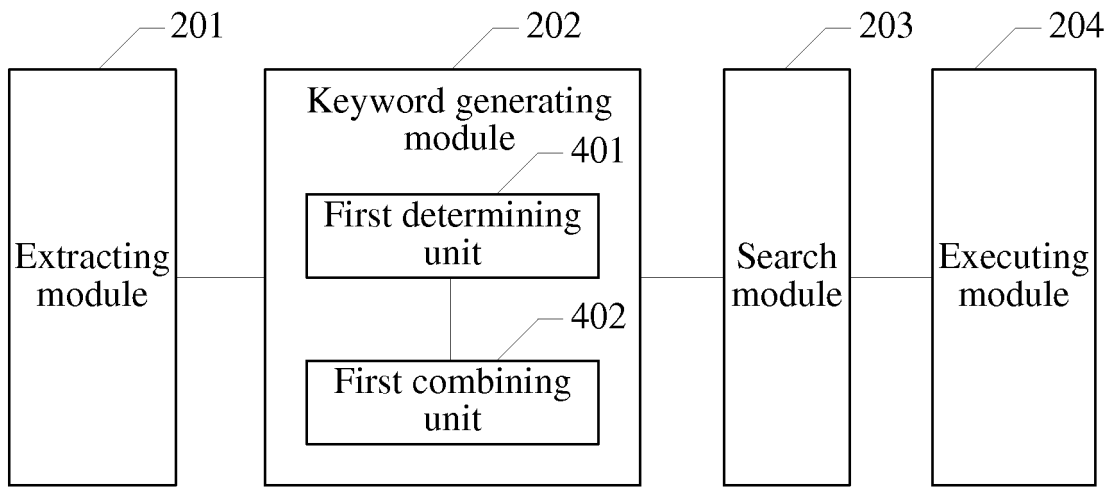


FIG. 4-a

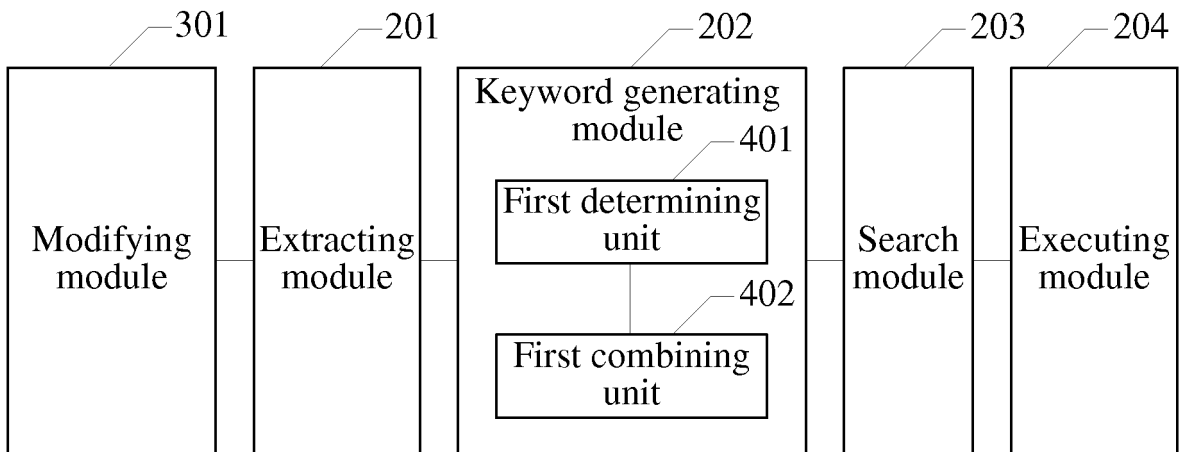


FIG. 4-b

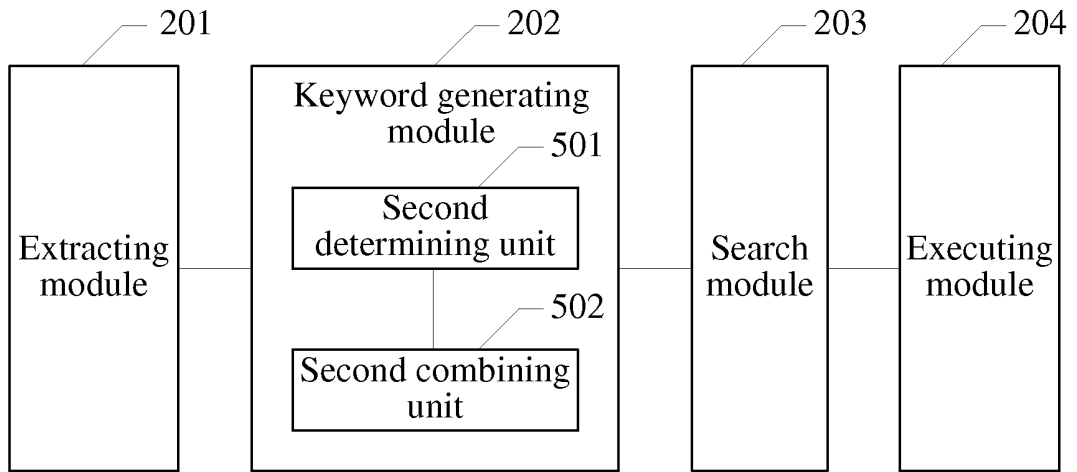


FIG. 5-a

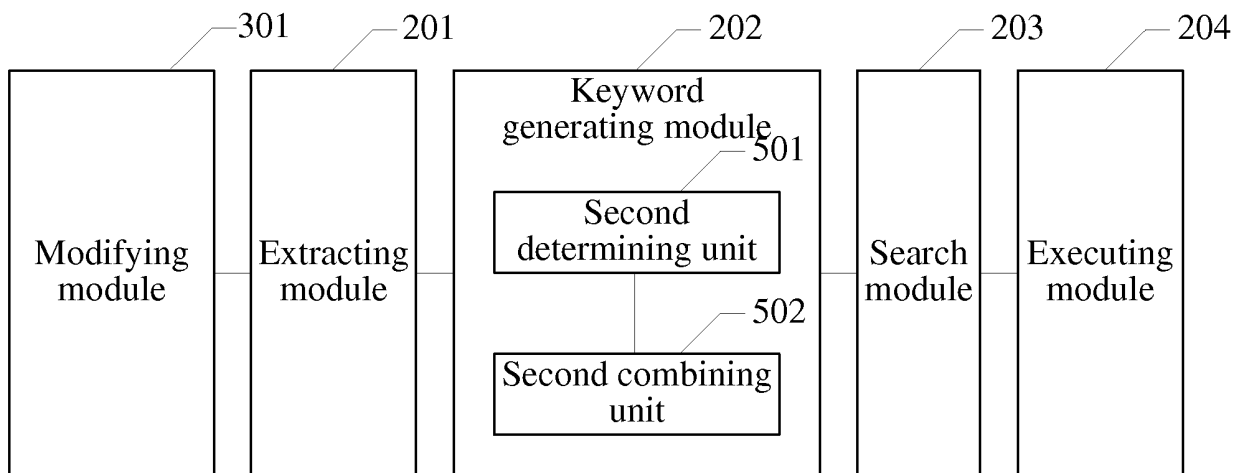


FIG. 5-b

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2014/081087

|                                                                                                                                                                                                               |                                                                                                                                                                                                                                                  |                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| <b>A. CLASSIFICATION OF SUBJECT MATTER</b>                                                                                                                                                                    |                                                                                                                                                                                                                                                  |                       |
| H04L 12/741 (2013.01) i                                                                                                                                                                                       |                                                                                                                                                                                                                                                  |                       |
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                             |                                                                                                                                                                                                                                                  |                       |
| <b>B. FIELDS SEARCHED</b>                                                                                                                                                                                     |                                                                                                                                                                                                                                                  |                       |
| Minimum documentation searched (classification system followed by classification symbols)                                                                                                                     |                                                                                                                                                                                                                                                  |                       |
| H04L; H04W; H04Q; H04B                                                                                                                                                                                        |                                                                                                                                                                                                                                                  |                       |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched                                                                                 |                                                                                                                                                                                                                                                  |                       |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)                                                                                  |                                                                                                                                                                                                                                                  |                       |
| CNPAT, CNKI, WPI, EPODOC: flow, openflow, table, match, multi, keyword, finding, extract, draw                                                                                                                |                                                                                                                                                                                                                                                  |                       |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                 |                                                                                                                                                                                                                                                  |                       |
| Category*                                                                                                                                                                                                     | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                               | Relevant to claim No. |
| PX                                                                                                                                                                                                            | CN 103354522 A (HUAWEI TECHNOLOGIES CO., LTD.) 16 October 2013 (16.10.2013) description, paragraphs [0044] to [0115]                                                                                                                             | 1-8                   |
| A                                                                                                                                                                                                             | CN 102957603 A (SHENGKE NETWORK (SUZHOU) CO., LTD.) 06 March 2013 (06.03.2013) the whole document                                                                                                                                                | 1-8                   |
| A                                                                                                                                                                                                             | CN 103095583 A (SHENGKE NETWORK (SUZHOU) CO., LTD.) 08 May 2013 (08.05.2013) the whole document                                                                                                                                                  | 1-8                   |
| A                                                                                                                                                                                                             | US 2008/0019360 A1 (SUN MICROSYSTEMS, INC.) 24 January 2008 (24.01.2008) the whole document                                                                                                                                                      | 1-8                   |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                              |                                                                                                                                                                                                                                                  |                       |
| * Special categories of cited documents:                                                                                                                                                                      | "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention                                              |                       |
| "A" document defining the general state of the art which is not considered to be of particular relevance                                                                                                      | "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone                                                                     |                       |
| "E" earlier application or patent but published on or after the international filing date                                                                                                                     | "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art |                       |
| "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)                                       | "&" document member of the same patent family                                                                                                                                                                                                    |                       |
| "O" document referring to an oral disclosure, use, exhibition or other means                                                                                                                                  |                                                                                                                                                                                                                                                  |                       |
| "P" document published prior to the international filing date but later than the priority date claimed                                                                                                        |                                                                                                                                                                                                                                                  |                       |
| Date of the actual completion of the international search                                                                                                                                                     | Date of mailing of the international search report                                                                                                                                                                                               |                       |
| 10 August 2014                                                                                                                                                                                                | 24 September 2014                                                                                                                                                                                                                                |                       |
| Name and mailing address of the ISA<br>State Intellectual Property Office of the P. R. China<br>No. 6, Xitucheng Road, Jimenqiao<br>Haidian District, Beijing 100088, China<br>Facsimile No. (86-10) 62019451 | Authorized officer<br><br>RAN, Jianguo<br><br>Telephone No. (86-10) 61648270                                                                                                                                                                     |                       |

Form PCT/ISA/210 (second sheet) (July 2009)

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
PCT/CN2014/081087

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| Patent Documents referred in the Report | Publication Date | Patent Family | Publication Date |
|-----------------------------------------|------------------|---------------|------------------|
| CN 103354522 A                          | 16 October 2013  | None          |                  |
| CN 102957603 A                          | 06 March 2013    | None          |                  |
| CN 103095583 A                          | 08 May 2013      | None          |                  |
| US 2008/0019360 A1                      | 24 January 2008  | None          |                  |

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**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- CN 201310269726 [0001]